Magnetic Transducer with Pedestal Pole Piece Structure

Related Applications

Pending U.S. patent application bearing serial number 09/154,527, commonly assigned with the present application, describes a head with laminated pole pieces with a P1 pedestal domain control element and is hereby incorporated into this application by reference.

Field of the Invention

The invention relates to the field of magnetic transducers (heads) having inductive write heads and more particularly to the structure of and the process for making the pole pieces and coil for the write head.

Background of the Invention

A typical prior art disk system is illustrated in Figure 1. In operation the magnetic transducer 10, usually called a "head," is attached to an arm or actuator 13 and flies above the rotating disk 16. A voice coil motor 19 (VCM) pivots the actuator 13 to position the magnetic transducer 10 over selected circumferential tracks on the disk 16. The disk 16 is attached to spindle 18 that is rotated by a spindle motor (not shown). The disk 16 comprises a substrate on which a plurality of thin films are deposited. The thin films include ferromagnetic material that is used to record the magnetic transitions written by the magnetic transducer 10 in which information is encoded. A tape based storage system uses a magnetic transducer in essentially the same way as a disk drive, with the moving tape being used in place of the rotating disk 16.

The magnetic transducer 10 is composed of elements that perform the task of writing magnetic transitions (the write head 23) and reading the magnetic

transitions (the read head 12) as illustrated in Figure 2. The electrical signals to and from the read and write heads 12, 23 travel along conductive paths (leads) (not shown) which are attached to or embedded in the actuator 13. Typically there are two leads each for the read and write heads 12, 23.

Figure 2A is a midline section of one type of prior art magnetic transducer 10A. The components of the read head 12 are the first shield (S1), two insulation layers 107, 109 which surround the sensor element 105 and the second shield 104 (P1/S2). This type of magnetic transducer 10A is called a "merged head" because the P1/S2 layer 104 serves as a shield for the read head 12 and a pole piece for the write head 23A. The yoke also includes a second pole piece 103 (P2) which connects with P1/S2 104 at the "back gap" (BG). The term "back gap" it should be noted is used in the art to mean the back of the yoke. Historically there was a gap in the back of the yoke and the term "back gap" continues to be used even though the back of the yoke is now continuous. The P2 103 confronts the P1 104 across the write gap layer 42 to form the write gap 43 at the air bearing surface (ABS). The coil 37 in this particular prior art head is deposited on a layer of resist 106 which is used to define the zero throat height (ZTH) by forming a step on the gap layer 42. The imprecision inherent in creating the step in resist material, alumina, etc., make it difficult to reduce the distance between the ZTH and the ABS. This is one of the limitations encountered when attempts are made to reduce the track width of this type of head 10.

Figure 2B is a midline section of a second type of prior art magnetic transducer 10B. There are two significant differences between the magnetic transducers 10A and 10B in Figures 2A and 2B. One difference is that the yoke in magnetic transducer 10B has three pole pieces P1 104, P2 103A and P3 103B. The P2 103A is formed at the write gap 43 a separate element. The third pole piece 103B (P3) is stitched to P2 103A and is connected to the P1 104 at the back gap (BG) to complete the yoke. Typically write heads 23 only have one coil layer 37, but the particular write head 23B shown has two coil layers which be called coil1 37 and coil2 57. The turns of both coil1 and coil2 are

routed between the write gap 43 and the back gap (BG) and then around behind the yoke. The P3 103B arches over the resist mound 111 which surrounds the coil(s). In either of the prior art write heads 23A, 23B the angle at which the bottom surface of P2 moves away from the ZTH point is typically far less than 90 degrees which results in efficiency losses through flux leakage.

As the required recording densities increase the width of the written track must decrease. For example, 40 Gb/in^2 requires an effective pole tip size of 0.35 microns. However, the coercivity of the ferromagnetic thin films on the disk must increase and the recording speed must increase. The needed write head must have high magnetic efficiency and low inductance. These requirements make it necessary to place the inductive components closer to the pole tips than is possible using the prior art.

Summary of the Invention

Applicant discloses a magnetic transducer with a write head with a pedestal pole piece on P1 and a planarized gap layer with single and multilayer coil embodiments and planarized P3 embodiments. The P1 pedestal and at least one coil are formed on essentially planarized surfaces which allows maximum precision to be obtained from the photolithography. The P1 pedestal defines the zero throat height (ZTH) with a 90 degree apex angle which cuts down flux leakage and improves efficiency. The P1 pedestal allows the distance from the ZTH to the ABS to be reduced which allows the coil turns to be located closer to the write gap to increase the magnetic efficiency. In one family of embodiments the first and second coils are disposed on opposite sides of the gap layer. The yoke of the write head preferably has upper and lower flux closure pieces at the back which facilitate in making P1 and P3 planar. Various combinations of these features allow heads according to the invention to be made with a very short yoke with resulting improved efficiency. In addition the

head may be made with a physical P2 tip size under one micron and an effective P2 size which is comparably small.

In a preferred embodiment of a process for fabricating a head according to the invention, the P1 layer is planarized to allow increased precision in the formation of the P1 pedestal and the first coil. A thin layer of dielectric material is deposited over the planarized P1 surface to provide a surface for formation of the coil. The first coil is then formed using prior art techniques, but because the surface is well planarized, the pitch of the coil can be made very small. In the next phase in this embodiment the P1 pedestal and the lower back flux closure at the back of the yoke are formed on the planarized P1. In another embodiment the first coil is formed before the P1 pedestal and lower back flux closure. In each of these embodiments the wafer is planarized after a thick layer of dielectric material is deposited over the first coil and the P1 pedestal and lower back flux closure. This is an advantage of the invention, since the gap layer is then formed on a planarized surface and in turn provides a planar surface for the precise formation of the P2 tip and the second coil. After the gap layer is deposited, it is etched away over the lower back flux closure. At this point the ferromagnetic material for the P2 pole piece and the upper back flux closure is deposited. The P2 pole piece confronts the P1 pedestal across the gap layer to form the write gap. The upper back flux closure contacts the lower back flux closure to form the back of the yoke structure in the back gap. The second coil is fabricated on the gap layer and then covered with protective material. The wafer at this point can optionally be planarized to improve the surface for the subsequent deposition of P3. The P3 in this embodiment extends from at least the stitch area of P2 over the second coil and onto the upper back flux closure completing the yoke. If the optional planarization step has been performed, then the P3 will be completely planar. The P3 may also be laminated. The P3 may extend over the P2 pole piece to the ABS or it may extend only over a rear stitch portion of the P2. Optionally a third coil may be stacked above the second coil. In this case, the P3 arches up from the P2 pole piece over the third coil and then down to contact the upper back flux closure.

Embodiments according to the invention will also be described in which the coil below the gap layer is omitted.

Brief Description of the Drawings

Figure 1 is an illustration of a prior art disk drive in which the head of the invention can be embodied, showing the relationships between the head and associated components.

Figure 2A is a section, perpendicular to the air bearing surface, of a prior art transducer with two coil layers. Figure 2B is a section, perpendicular to the air bearing surface, of a prior art transducer with two coil layers.

Figure 3 is a section of a transducer according to the invention, perpendicular to the air bearing surface, during fabrication after the first coil has been formed.

Figure 4 is a section of a transducer according to the invention, perpendicular to the air bearing surface, after the P1 pedestal and lower back flux closure have been formed.

Figure 5 is a section of a transducer according to the invention, perpendicular to the air bearing surface, after the state shown in Figure 4, showing a layer of dielectric material deposited for planarization.

Figure 6 is a section of a transducer according to the invention, perpendicular to the air bearing surface, subsequent to the state shown in Figure 5, after planarization.

Figure 7 is a section of a transducer according to the invention, perpendicular to the air bearing surface, after the state shown in Figure 6, after the gap layer has been deposited and etched at the back to expose the lower back flux closure.

Figure 8 is a section view of a transducer according to the invention, perpendicular to the air bearing surface, after the state shown in Figure 7, after ferromagnetic material has been deposited to form the P2 pole piece and the upper back flux closure, and after the second coil has been formed.

Figure 9 is a plan view of a transducer according to the invention, perpendicular to the air bearing surface, showing the relationships been the P1 pedestal (before notching), the P2 pole piece, the coils and the upper back flux closure.

Figure 10 is a section view of a transducer according to the invention, perpendicular to the air bearing surface, subsequent to Figure 8, after all of the components of the write head have been formed.

Figure 11 is a section view , perpendicular to the air bearing surface, of an alternative transducer embodiment according to the invention with a planarized P3, showing all of the major components of the write head have been formed.

Figure 12 is a section view of a transducer embodiment according to the invention, perpendicular to the air bearing surface, having three coil layers.

Figure 13 is a section view of a partially completed transducer according to the invention, perpendicular to the air bearing surface, illustrating a second method of fabricating a head according to the invention, after the P1 pedestal and the lower back flux closure have been fabricated.

Figure 14 is a section view of the partially completed transducer according to the invention, perpendicular to the air bearing surface, subsequent to that of Figure 13, after the first coil has been fabricated.

Figure 15 is a section view, perpendicular to the air bearing surface, of an alternative transducer according to the invention which has a single coil and a nonplanarized P3 which extends to the air bearing surface.

Figure 16 is a section view, perpendicular to the air bearing surface, of an alternative transducer according to the invention which has a single coil and a planarized P3 which does not extend to the air bearing surface.

Detailed Description of the Invention and the Preferred Embodiments

It is conventional for thousands of heads to be manufactured simultaneously on a single wafer. For simplicity the following will typically describe the actions or structures for a single head, but it is to be understood that most of the process steps are performed over the entire wafer and are, therefore, forming structures for thousands of heads simultaneously. The invention relates to the write head portion of the magnetic transducer and does not place limits on the type of read head that can be used with it. Typically the read head portion of the transducer is fabricated first, but transducers with the write head portion fabricated first have been described in the prior art. A write head according to the invention may be fabricated before or after the read head portion of the transducer.

The relative sizes of the components shown in the figures are not presented according to scale, since the large range of sizes would make the drawing unclear. The relative sizes/thickness of the components are according to prior art principles except where noted below. The hatching lines are not

intended to represent the material composition of a structure, but are used only to distinguish structures and aid in the explanation of the process of making the write head.

First Method of Fabricating a Write Head According to the Invention

Reference is made to Figure 3 to begin the description of the process of making a first embodiment of a write head 23C of the invention. The section view is perpendicular to the air bearing surface (ABS) (not shown) which will be on the left of the figure after the wafer is sliced. The actual ABS is delineated when the heads are cut from the wafer. The first pole piece (P1) 30 is deposited as in the prior art, on a generally planar surface and is made of standard ferromagnetic material. The P1 30 may optionally serve as a shield for the read head (not shown) if the head is a merged head. The upper surface of P1 30 is preferably planarized to establish a well controlled surface for the subsequent formation of the first coil 37 (coil1). Achieving the smallest pitch in coil1 requires that P1 be planarized. A thin layer of dielectric material such as alumina 31 is vacuum deposited over P1 30 to provide a base for coil1 37. Since the alumina 31 is vacuum deposited, it will not significantly disrupt the planarity of the surface. The thickness of the alumina layer 31 has been significantly exaggerated in this illustration in relation to the coil1 37 height. The alumina 31 only needs to be thick enough to provide the required insulating surface. The coil1 37 is fabricated using prior art techniques and materials, e.g., seed layer deposition, photolithography, copper plating, etching and seed removal. Although prior art techniques are used, the well controlled surface of the alumina 31 allows the pitch of the turns of coil1 37 to be smaller than would otherwise be possible. This is one of the advantages of the method of the invention, since a smaller coil pitch is required to improve the write head over the prior art. For similar reasons, the first turn of coil1 37 can be placed within approximately 1 pitch spacing of the P1 pedestal 33. Coil1 37 is shaped the same as prior art coils. After coil1 37 has been formed, the alumina layer 31 must be etched away to

form vias V1 and V2 in which ferromagnetic material will subsequently be deposited. The turns of coil1 37 are disposed between V1 and V2, making V1 lie outside of the coil and V2 lie inside of the coil.

In Figure 4 a subsequent point in the fabrication process is illustrated. After the vias V1 and V2 have been formed, the coil1 37 is protected and insulated preferably by photoresist material 38 which fills in between the coil turns, but is removed from the V1 and V2 areas. At this point the wafer is ready for formation of the P1 pedestal 33, which will serve as the P1 pole tip, and the lower back flux closure 35 which will connect P1 and the upper back flux closure at the back of the completed yoke (not shown). The P1 pedestal 33 and lower back flux closure 35 are preferably formed simultaneously from ferromagnetic material using prior art electroplating techniques. The P1 pedestal 33 and lower back flux closure 35 should extend at least to the height required to achieve the desired final thickness of coil1 37.

Referring to Figure 5, a relatively thick layer of a dielectric material 41, preferably alumina, has been deposited to fill in any gaps between the insulating material 38 (photoresist) around coil1 37 and the P1 pedestal 33 and lower back flux closure 35. This layer of dielectric material 41 prepares the wafer for planarization. Photoresist may be used in place of alumina between the P1 pedestal 33 and the lower back flux closure 35. Figure 6 illustrates the state of the fabrication after planarization, for example, by chemical-mechanical-polishing (CMP). The wafer surface material is removed to the level marked as line BB to expose and planarize the tops of the P1 pedestal 33 and lower back flux closure 35 . Preferably the tops of the turns of coil1 37 are also exposed and planarized as shown. The only part of the alumina 41 which remains is that which was needed to fill the spaces described above.

In Figure 7 a gap layer 43 has been deposited on the planarized surface and then etched away to form a via V3 exposing the top of the lower back flux closure 35 . The thickness of the gap layer 43 defines the length of the write gap. The gap layer 43 is formed from nonferromagnetic material as in the prior art, for example, alumina.

Figure 8 shows that the upper back flux closure 45 has been formed in V3. The P2 pole piece 49 has been deposited on the gap layer 43 to confront the P1 pedestal 33 to form the write gap. The upper back flux closure 45 and P2 pole piece 49 are preferably formed simultaneously from ferromagnetic material using standard photolithography and plating. It is now clear that the back side of the P1 pedestal 33 defines the ZTH, since the planar bottom surface of P2 49 extends back farther than the P1 pedestal 33. It is also clear that the P1 pedestal 33 defines the ZTH with a 90 degree apex angle since the back of P1 pedestal 33 is perpendicular to the bottom surface of P2 pole piece 49. Having a 90 degree apex angle cuts down flux leakage, as well as, having the coil1 37 located closer to the write gap improves the efficiency of the head.

Next temporary protective material 63 such as photoresist is applied over the two ferromagnetic structures 45, 49 to protect them during fabrication of the second coil (coil2) 57. The coil2 57 is formed on the gap layer 43 which is a well planarized surface since it is vacuum deposited onto a planarized surface (BB) . As was noted for coil1 37, the surface on which the coil2 57 is formed is a significant factor in the minimum coil pitch which can be obtained.

Referring to Figure 10, after the second coil 57 is completed the temporary protective material 63 (shown in Figure 8) is removed and a permanent protective layer 65 is formed on the second coil 57 as shown in Figure 10. The permanent protective layer 65 can be patterned and removed from the stitch areas of the P2 pole piece 49 and the top of the upper back flux closure 45 . The final ferromagnetic component, the P3 53, is deposited on the stitch area of the P2 pole piece 49, over the permanent protective layer 65, and onto the upper back flux closure 45 to complete the yoke structure. The P3 53 can be formed using standard photolithography and electroplating techniques, but vacuum deposition and patterning by ion milling could also be used.

Although the invention does not depend on particular dimensions, some comments about the relative dimensions may be instructive. For example, the thickness of the P2 pole piece 49 is preferably approximately the same as the ZTH. The ZTH in turn is typically limited by the precision with which the ABS

can be formed by lapping, i.e., the lapping tolerance. The ZTH is also typically approximately 0.5 to 1.0 times the track width. An embodiment of the head of the invention could, for example, be made with a P2 pole piece 49 thickness of 1 to 3 microns and an approximately equal ZTH. The gap layer thickness is preferably about 0.25 to 0.33 times the width of the track. In addition, the head may be made with a physical P2 tip size under one micron.

From the state shown in Figure 10 only prior art structures which are not shown, such as vias connecting coil1 37 and coil2 57, leads and protective material, are needed to complete the write head 23. As in prior art heads having two or more coils, the coils 37, 57 are electrically connected in series to a single pair of external pads (not shown), so that electric current can be driven through both coils to induce a magnetic field in the ferromagnetic yoke structure.

An alternative embodiment of a write head 23D according to the invention is illustrated in Figure 11. Two independent, optional modifications from transducer 23C are shown. The method of fabricating write head 23D uses an additional planarization step after the permanent protective layer 65 is formed on the second coil 57. The selected planarization line is shown as line CC. This alternative planarizes the tops of the P2 pole piece 49 and upper back flux closure 45 , as well as, planarizing the permanent protective layer 65, so that the P3 53A can be fully planar. In this case, however, the tops of the turns of coil2 57 cannot be exposed, since this would cause the turns of coil2 57 to be shorted out. The shape of the P2 pole piece 49 in plan view can be that shown in Figure 9. In yet another alternative the P3 53A can also be laminated. A second optional modification illustrated in Figure 11 extends the P3 53A out to what will become the ABS. The option of extending P3 53A to the ABS may be used without planarizing along line CC.

Thus far the structures have been described in section view. To show the relative widths of the key structures, Figure 9 is a plan view showing the P2 pole piece 49, the P1 pedestal 33, coil2 57 and the upper back flux closure 45. Coil1 37 is shown in phantom, since it is below the surface at this stage. The ABS will be along the left side of this view as in the previous figures. This view shows that

the P1 pedestal 33 is preferably wider than the tip of the P2 pole piece 49, for example, 10 or more times wider. This allows the P1 pedestal 33 to be trimmed or notched to match the tip of the P2 pole piece 49 by ion milling as is performed in the prior art. The P1 pedestal 33 also provides the domain control which is fully described in pending U.S. patent application bearing serial 09/154,527 which is commonly assigned with the present application. The P2 pole piece 49 in a plan view is preferably shaped with a narrow "neck" extending over the top of the P1 pedestal 33. As the P2 pole piece 49 extends back toward the coil2 57, it widens out to provide a stitch area on which P3 53 (not shown) can more easily be deposited. Subject to the constraints of the P3 53 stitching requirements, the length of the P2 49 is kept relatively short because it is important for the second coil 57 to be close to the ABS. The top of the upper back flux closure 45 is preferably larger in area than tip of the P2 pole piece 49.

Figure 12 illustrates a completed write head 23E according to an alternative embodiment of the invention. In the write head 23E, a third coil (coil3 77), has been formed on top of coil2 57 separated by protective material 65. Both coil2 57 and coil3 77 are covered by the arching P3 53B which is shown extending to the ABS, but alternatively may be stopped short of the ABS as noted previously.

Second Method of Fabricating a Write Head According to the Invention

A second method of fabricating a write head 23F according to the invention will be described. Reference is made to Figure 13 which shows that P1 pedestal 33 and lower back flux closure 35 have been formed on the planar surface of P1 30. A dielectric layer 31, preferably alumina, has been deposited to provide an insulated base on which to fabricate the first coil (not shown). Note that this method forms the P1 pedestal 33 and the lower back flux closure 35 before the first coil in contrast to the first method described above. Figure 14 shows write 23F after the first coil 37 has been formed on top of the dielectric

layer 31. The first coil 37 is formed using prior art techniques. A dielectric layer 54, such as thick alumina, is preferably deposited over wafer to protect the first coil 37 and to aid in planarization down to the line BB. The planarization process must continue until sufficient material has been removed so that the P1 pedestal 33 and lower back flux closure 35 are exposed and planarized. The tops of the turns of the first coil 37 may optionally be exposed. After the planarization step the process continues as in the first embodiment described above.

Third Method of Fabricating a Write Head According to the Invention

A third method of fabricating a write head 23G according to the invention will be described. Reference is made to Figure 15 which shows that P1 pedestal 33 and lower back flux closure 35 have been formed on the planar surface of P1 30 as before. In this embodiment there is no coil below the gap layer 43 and, therefore, all of the fabrication steps relating to the formation of the first coil in the previous methods are omitted. The dielectric layer 54, preferably alumina, is deposited to fill the wafer to aid in planarization down to the line BB. After the planarization step the process continues as in the first method embodiment described above. The previously described optional modifications can be applied as well. For example, the P3 53C may extend to the ABS as is shown in Figure 15. Figure 16 illustrates other alternatives by showing that the P3 53D may be planarized and may be stopped short of the ABS. Although not shown, an additional coil may be placed above the coil 57 as has been previously described.

Other variations and embodiments according to the invention will be apparent to those skilled in the art which will nevertheless be with the spirit and scope of the invention.